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THE ICE WELL FOR THE DAIRY FARM

By J. R. Dawson, *senior dairy husbandman, Division of Breeding, Feeding, and Management Investigations,* and A. L. Watt, *Superintendent of the United States Dairy Experiment Station at Mandan, N. Dak., Bureau of Dairy Industry* [1]

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INTRODUCTION

In the fall of 1928 an experimental ice well was constructed by the Bureau of Dairy Industry at the United States Dairy Experiment Station at Mandan, N. Dak., in cooperation with the North Dakota State Agricultural College. Successful results were obtained in freezing ice in the well that winter and in experiments in cooling cream the following summer. Good results were also obtained during the second year's work in freezing ice in the well and in milk- and cream-holding experiments. Each year since then the well has been filled with ice and used to obtain supplementary experimental data, and to demonstrate this method of refrigeration. Observations during the nine seasons 1929 to 1937 are reported in this circular, which was first issued after the second, or 1930, season.

The ice-well method of holding cream on dairy farms has proved to be very successful in the northern Great Plains area of the United States. This area is rather sparsely settled, and many farmers live at considerable distances from a cream station or shipping point. Natural ice is scarce because of the lack of natural bodies of water such as rivers and lakes. These circumstances make it difficult for the farmers to have a supply of natural ice during three or four of the hottest months in the summer, and it is difficult for farmers without ice to market their cream in sweet condition.

[1] J. R. Dice, head of the dairy department of North Dakota Agricultural College and Agricultural Experiment Station, acted in an advisory capacity.

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Farmers who live at a considerable distance from cream stations or shipping points and find it too expensive to deliver their cream frequently, can hold it for a longer period if they have ice wells, and still market it as sweet cream, thus obtaining the benefit of the increased price. For example, in the Mandan-Bismarck section the price of sweet-cream butterfat is considerably higher than that of sour-cream butterfat. During the summer of 1935 the price of sour-cream butterfat to producers averaged about 22 cents per pound for the 6-month period May to September, but the price of No. 1 sweet-cream butterfat was from 5 to 10 cents per pound higher. Dairymen obtaining this premium for sweet-cream butterfat increased their returns from 22 to 45 percent.

The ice-well "refrigerator" primarily consists of a pit in the ground in which a solid cake of ice is formed in winter. The usual manner of forming a solid cake of ice is by sprinkling or throwing from 5 to 15 gallons of water at a time into the pit a number of times daily in freezing weather. Another method sometimes employed is to put blocks of natural ice into the pit after the cake is started, pack the chinks with fine ice, and freeze them together with water. After the ice cake is frozen the pit is closed, and used as a refrigerator or ice box for dairy and other food products during the summer months.

CONSTRUCTION

A pit 8 feet square and 9½ feet deep was dug in a well-drained site about 10 feet from the milk house (fig. 1). The soil was rather heavy. Several large stones were encountered and had to be removed. To insure good drainage from the bottom, a layer of coarse stone and gravel 1½ feet deep was put in the bottom of the pit. At each corner of the bottom of the pit holes were dug with a post-hole digger, and the holes were filled with stone and gravel. In light gravelly soils the layer of coarse stone and gravel in the bottom may not be needed.

The sides of the pit were then lined with cheap, rough lumber; 2-by 4-inch studs were placed upright 2 feet apart against the dirt sides, and rough 1-inch boards were nailed to these. This construction gives a 4-inch air space, if the dirt walls do not cave in, which is good insulation against the soil heat. The lumber was not treated in any way, and after nine seasons' use there has been but little rotting. On taking up the floor in the fall after a season's use, patches of white mold have been found occasionally on the upper side walls and the lower side of the floor. These areas were brushed, scrubbed, and sprinkled with a disinfecting solution, and no injury to the wood has been noticed.

A small, inexpensive house was built over the pit (fig. 2). Hinged, board windows were made in three sides of the house to insure good draft. These are dropped down and left open during freezing weather when water is being frozen. In the summer they are kept tightly closed. A door was built in the front side of the house, which is also kept open in the winter and closed in the summer. A small, gable-window ventilator was provided in one end near the roof.

The floor was built in sections so that the entire floor can be removed during the freezing period. The floor is of double thickness, with three thicknesses of red-rosin building paper between the boards.

Care was taken to have the sections fit closely in order that the pit might be closed tightly in summer.

A tightly fitting trap door (figs. 3 and 4) was constructed in the central section of the floor. Through this door a wooden rack for the cream and milk cans is lowered and raised by means of rope and pulley, the pulley being fastened to a rafter above. After the rack has been lowered to the ice block, the trap door is closed tightly.

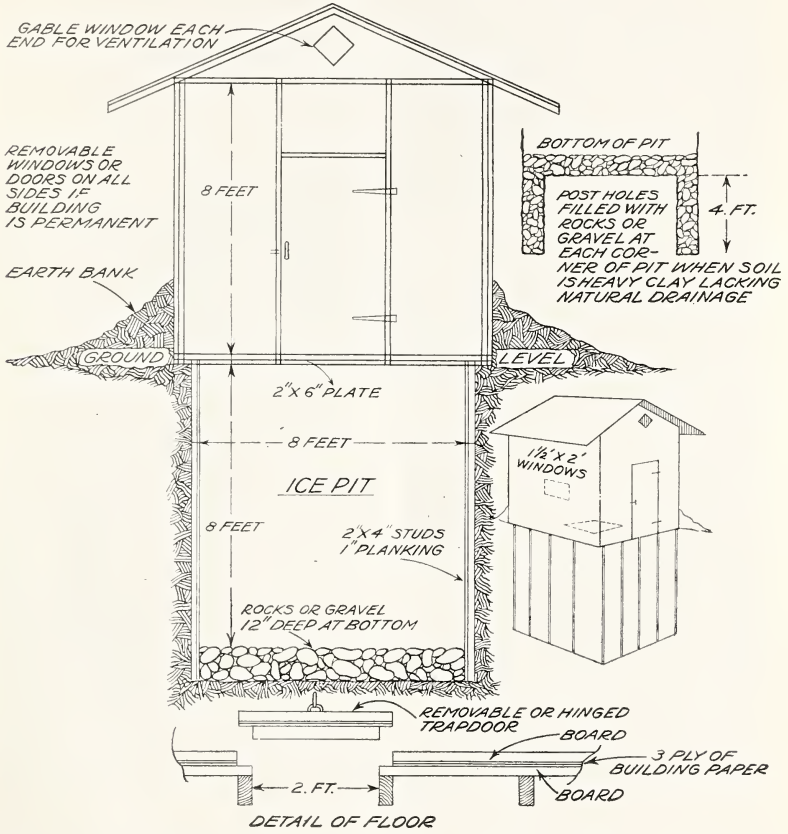

FIGURE 1.—Details of ice well and building. There seems to be no reason why the ice well cannot be of any practical size desired; the measurements given are only suggested. (Reproduced by courtesy Department of Agriculture, Province of Saskatchewan, Canada.)

OBSERVATIONS ON FORMING THE ICE BLOCK DURING THE WINTER OF 1928–29

FREEZING A SOLID BLOCK

Early in January 1929 the doors and windows of the house were opened and the floor was removed. Water was sprinkled on the gravel in the bottom of the pit at frequent intervals during the day. This was continued for 5 days. At the end of this time a 1½-inch

layer of ice had been established on the bottom of the pit. Considerable difficulty was experienced in getting this foundation layer of ice formed because the water would drain away before it would freeze. This problem was solved, however, by throwing a few shovelfuls of snow into the pit and making a slush with water. After the first layer of ice was formed several bucketfuls of water were

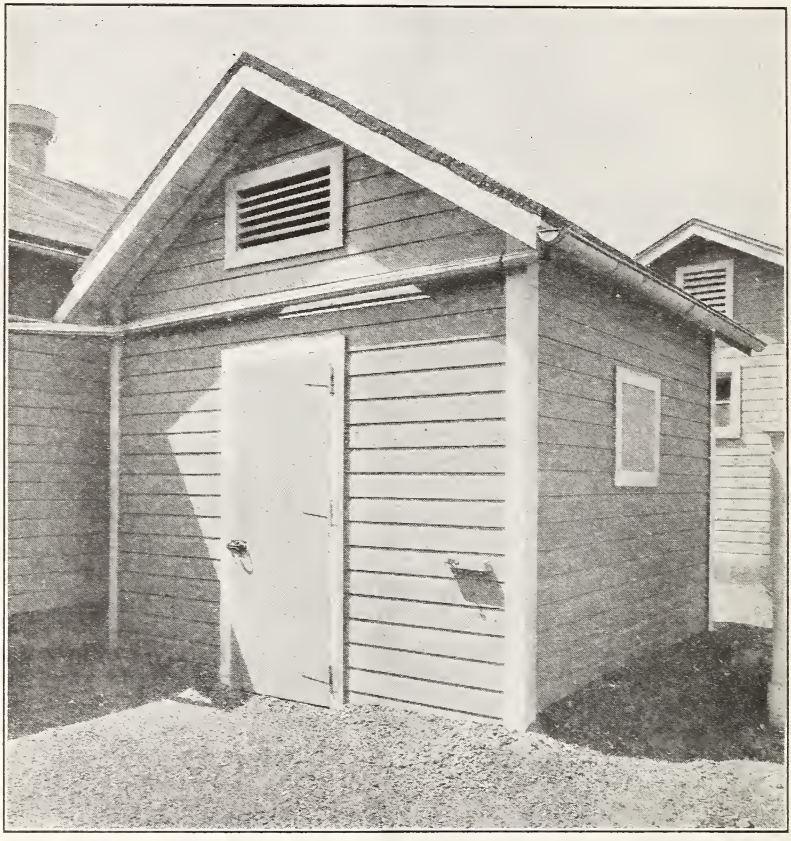

FIGURE 2.—The house over the ice well at Mandan. This picture was taken in the summer. The windows and doors are kept tightly closed as much of the time as possible in the summer, but open in the winter when the ice block is being frozen.

thrown in and allowed to freeze thoroughly before more water was added. The amount of water that was added depended on the outside temperature. On extremely cold days as much as 120 gallons of water was added. This was sufficient to make a 3-inch layer of ice. By the end of February a solid block of ice 8 feet square and 6½ feet deep, measuring 416 cubic feet, had formed. Freezing was stopped when the block was 6½ feet deep, so there would be room enough for a 5-gallon cream can between the top of the ice block and the floor of the house. The floor was then replaced and the door and windows tightly closed.

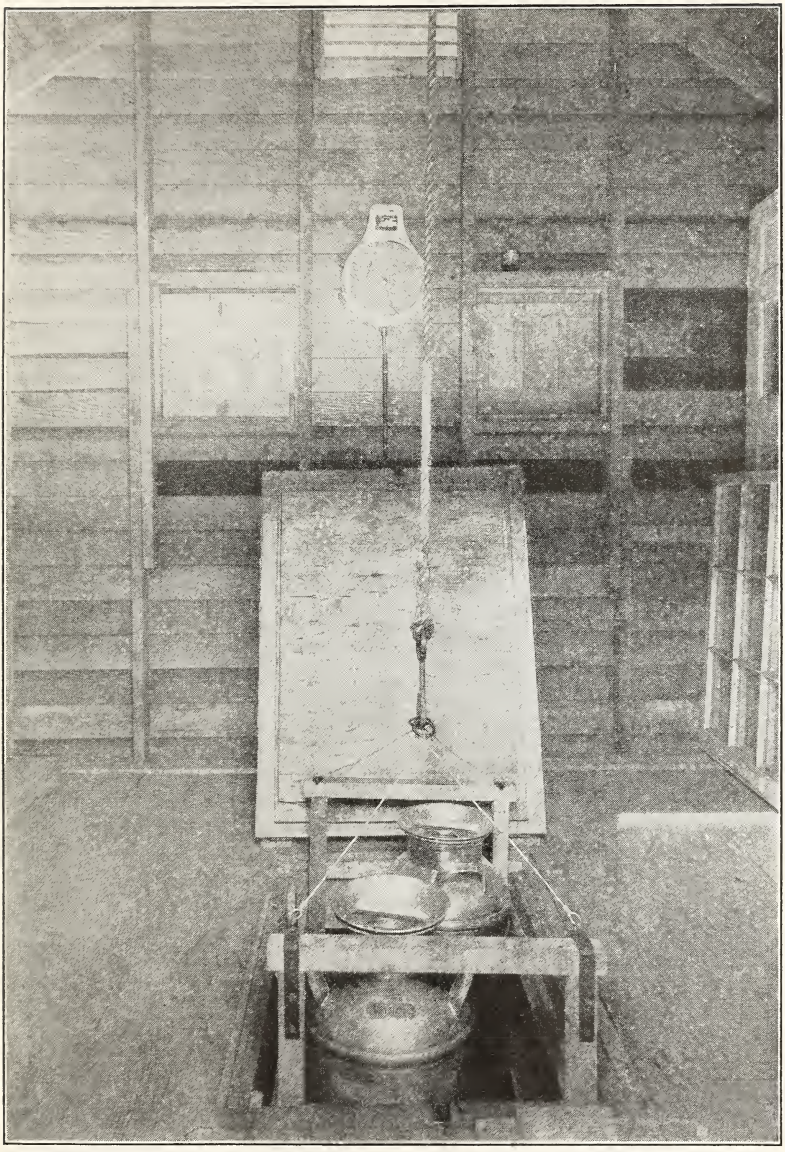

FIGURE 3.—Interior of ice-well house. Trap door in floor is open, and milk cans, on rack, are being lowered to the block of ice in the well below. The dial on the wall is that of a recording thermometer with which a record was made of the temperature in the pit, the bulb of the thermometer being in the pit.

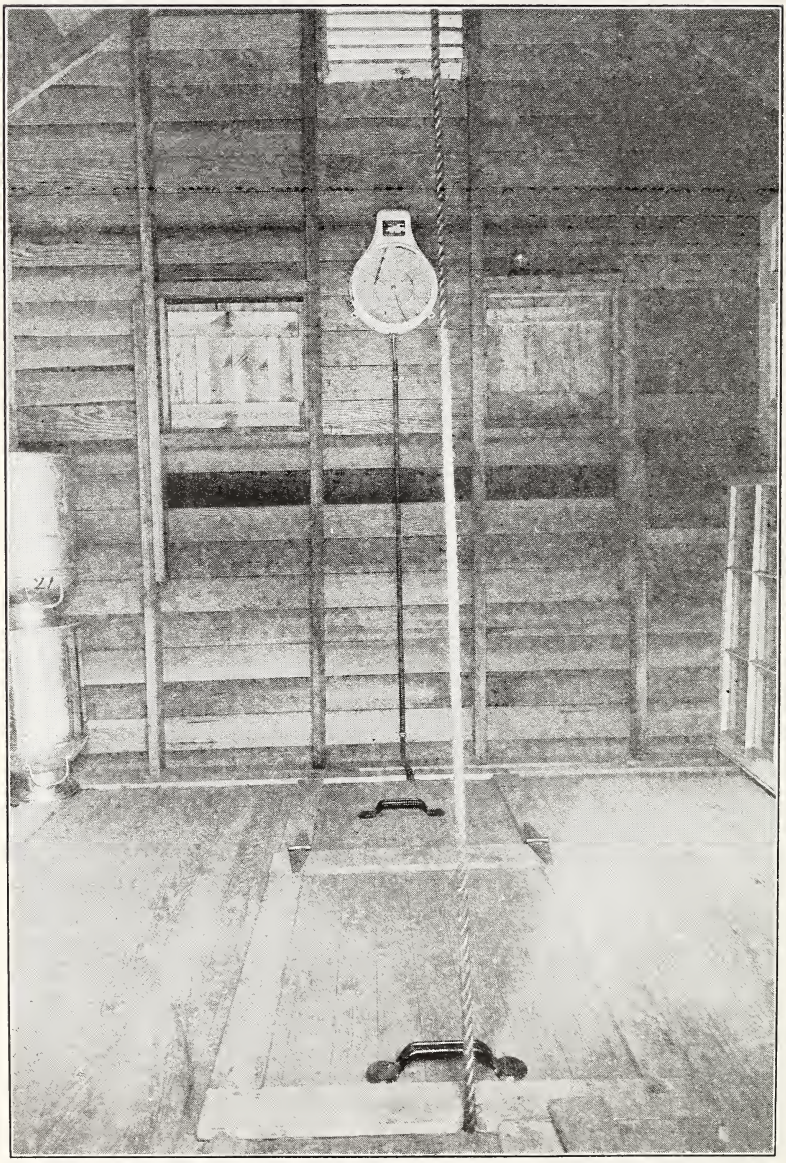

FIGURE 4.—Interior of the ice-well house, showing the trap door closed.

The cake was frozen in approximately 2 months, January and February, although some of the days during this period were too warm for satisfactory freezing. Table 1 gives the record of temperatures that prevailed during the period of this experimental work. In January 1929 the mean temperature was −2.9° F., with a high of 38° and a low of −33°. In February 1929, the mean was 4.6°, with a high of 33° and a low of −43°. There were only 3 days in January and February when the temperature went above freezing, and there were only 15 days during these 2 months when the temperature did not go below zero. It is readily seen that for this locality the weather was sufficiently cold and the low-temperature periods were long enough to insure sufficient freezing.

TABLE 1.—*Monthly temperatures at Mandan, N. Dak., 1929–37, for 9 months each year*

Month	1929	1930	1931	1932	1933	1934	1935	1936	1937
January:	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
High	38	31	59	43	52	49	47	30	34
Low	−33	−28	−9	−22	−20	−11	−32	−28	−37
Mean	−2.9	−.4	24.6	9.8	14.2	19.8	8.6	−3.8	−6.0
February:									
High	33	57	59	65	54	56	58	23	40
Low	−43	−11	0	−18	−38	−19	−5	−45	−27
Mean	4.6	24.3	30.4	15.7	10.6	23.6	27.6	−11.4	8.6
March:									
High	67	55	50	55	64	69	72	55	66
Low	5	−3	−7	−17	−2	−3	−17	0	4
Mean	32.2	28.0	27.2	20.5	31	28.2	27.6	28.2	28.6
May:									
High	81	87	93	91	91	102	74	92	94
Low	23	29	23	32	30	34	32	33	28
Mean	51.2	51.5	54.4	56.5	55.6	65.6	50.1	62.6	58.9
June:									
High	90	86	104	86	106	90	87	105	99
Low	36	43	43	49	46	48	37	42	36
Mean	62.9	64.5	69.6	67.5	73.2	66.0	66.2	69.2	64.6
July:									
High	106	102	107	99	102	106	100	114	100
Low	47	49	47	46	48	43	52	55	50
Mean	73.6	74.8	71.6	72.0	73.9	74.2	75.8	83.4	73.6
August:									
High	99	97	99	96	96	102	104	99	104
Low	38	45	45	43	40	33	33	48	52
Mean	70.6	71.3	67.5	69.7	69.3	69.8	68.0	72.6	75.4
September:									
High	102	88	105	94	97	89	98	95	94
Low	30	25	37	30	30	25	27	31	32
Mean	53.1	57.7	63.2	58.4	62.9	52.6	60.2	61.6	60.4
December:									
High	47	46	44	54	56	48	40	54	43
Low	−27	−1	−9	−17	−23	−22	−19	−21	−18
Mean	13.6	22.8	21.4	15.7	12.0	15.4	15.3	16.7	13.6

OPENING AND USE OF THE ICE PIT IN SUMMER

In 1929 the pit was opened and the use of the well for storing cream and other products begun on May 25. The ice lasted until September 28, a period of 126 days, or slightly more than 4 months. During this time fresh milk and cream were placed in the pit each day. Several hundred people visited the station in the course of the summer and were interested in seeing the ice well. Hardly a day passed but that the well was opened at least once to show it to visitors, and on some days it was opened five or six times. Undoubtedly this frequent opening of the well caused the ice to melt faster than it would have otherwise.

The mean temperatures for May, June, July, August, and September 1929, were 51.2° F., 62.9°, 73.6°, 70.6°, and 53.1°, respectively. The highest temperature of the summer was 106° on July 26. On 27 days in June, July, and August, the temperature reached 90° or higher.

NUMBER OF DAYS REFRIGERATION EACH SUMMER

The date of opening, the date of last ice, and the number of days use of the ice are given in table 2.

TABLE 2.—*Dates of opening ice well, dates when ice disappeared, and number of days ice lasted for the 9 years 1929–37*

Year	Date well was opened	Date of last ice	Days use of ice	Year	Date well was opened	Date of last ice	Days use of ice
			Number				*Number*
1929	May 25	Sept. 28	126	1934	May 17	Sept. 19	125
1930	May 4	do	147	1935	May 12	Oct. 6	147
1931	May 12	Sept. 13	124	1936	May 15	Sept. 21	129
1932	May 19	Sept. 3	107	1937	do	Sept. 19	127
1933	May 11	Sept. 16	128				
				Average			129

Each year the pit was opened for use in summer sometime in May, and the last ice was used up sometime during September except for 1935. The largest variation in the date of opening the well for use in summer for any 2 of the 9 years from 1929 to 1937 was 21 days. The total period of use in summer varied for different years. In 1930 and 1935 the ice lasted 147 days, and for six of the seasons it ranged from 124 to 129 days. In one season, 1932, it lasted only 107 days. The average for the 9-year period was 129 days.

RATE AND NATURE OF MELTING

Measurements were taken and notes made on the rate and nature of melting throughout the summer of 1929. In the 98-day period from May 25 to August 31 the top of the ice melted down a distance of 56 inches, or an average of 0.57 inch per 24 hours. The daily rate of melting from the top varied from 0.33 to 1.25 inches. Up to July 12 the melting was comparatively slow, but after that it was more rapid. The most rapid rate of melting (1.25 inches per day) was during the week of July 22, when the warmest weather of the summer occurred. The average rate of melting was 3.3 cubic feet of ice per day for the 126-day period from May 25 to September 28.

The rate of melting away from the walls of the well was practically the same on all sides, but there was a tendency for the north side to melt a little more rapidly than the others. A platform scale with a pit was located about 3 feet from the north side of the house, and that probably was responsible for the more rapid melting on that side. On August 31 the ice had melted a distance of 14 inches from the east, south, and west walls, and 15 inches from the north wall. The average rate of melting from each wall was 0.14 inch per day.

The first ice that melted was that along the side walls. For a short time this melting caused a slight depression along each side of the ice cake, in which a small quantity of water collected. This water was removed, and no more water collected on the block.

It was rather surprising to note that the ice directly under where the rack rested, melted somewhat slower than the rest of the cake resulting in a cone-shaped formation of ice on the top of the cake, where the rack rested. This formation was about 3 inches higher than the rest of the block. On July 23 this cone was leveled off to the level of the surrounding surface, and it did not form again.

The rate and nature of melting was similar for each year, depending somewhat on the amount of material stored in the well and the frequency with which it was opened.

TEMPERATURES IN THE PIT

Temperatures in the well during the summers of 1929 and 1930 were automatically recorded by a self-recording thermometer. The recording dial of this thermometer is seen in both figures 3 and 4, attached to the rear end wall of the house. The bulb was placed at three different heights above the ice block—1, 6, and 12 inches—and temperatures were recorded for several weeks at each height (fig. 5).

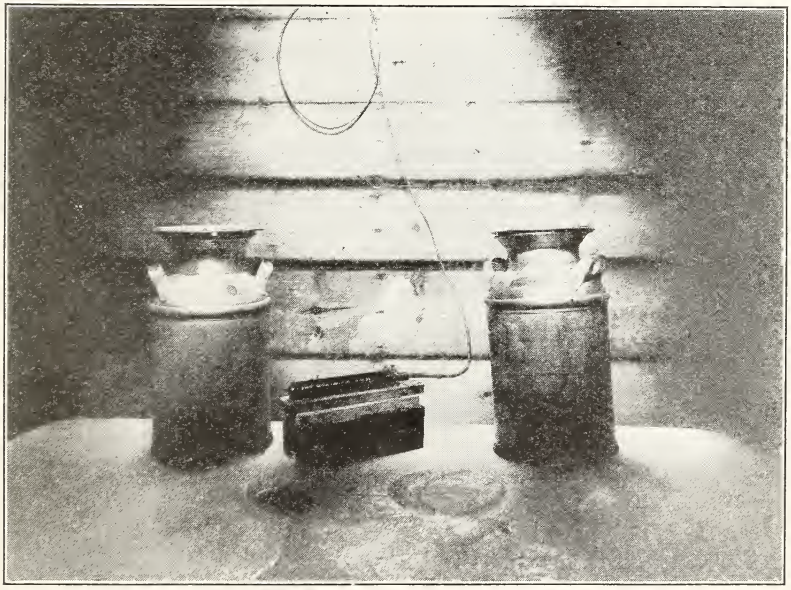

FIGURE 5.—Down in the ice well, showing the top of the ice block, with cans of cream setting directly on the ice, and with the bulb of the recording thermometer resting on a block of wood 6 inches above the ice. The thermometer tube was flexible, allowing the bulb to be placed in any position in the well.

Table 3 shows the variation in temperature at the different heights. At 6 inches above the ice block the temperature was decidedly higher than at 1 inch, and at 12 inches the readings were about the same as at 6 inches. None of the temperatures recorded were higher than 50.

TABLE 3.—*Temperatures at distances of 1, 6, and 12 inches above the ice block for two summers*

Height of thermometer bulb above ice block (inches)	Summer of 1929			Summer of 1930		
	Highest	Lowest	Average	Highest	Lowest	Average
	° F.	° F.	° F.	° F.	° F.	° F.
1	42	38	39	36	32	36
6	50	44	48	44	40	42
12	50	46	49	46	40	44

COOLING CREAM AND MILK

Several experiments in cooling cream were made in the 1929 season with small quantities, about 15 pounds in each lot. All of the cream was precooled with cold water before it was lowered into the ice well. With greater quantities of cream the results might have been somewhat different. The cream was precooled by putting the cream can in a container, through which the cooling water was circulated. The temperature of the cooling water averaged 52° F. The temperatures of the cream as it came direct from the separator at 7 a. m. averaged 80°. By 8:30 a. m. the cream had been cooled to a temperature of 56.3°. At this time it was placed in the rack on the ice block. The bottom of the can was approximately 1 inch above the ice. At 9:30 a. m., or at the end of an hour, the temperature of the cream was 52°; at the end of 3 hours it was 48°; in 4 hours it had dropped to 46°; and at 4:30 p. m., or in 8 hours, it had been cooled to 42°. The above data are the average for 20 samples. The cream was thoroughly stirred before temperatures were taken.

Other lots of cream were precooled, and the cans were set directly on the ice block. The average temperature of the cream when set on the ice block was 56.3° F. After 2 hours the temperature had dropped to 42°; in 4 hours the temperature was 37°; and in 6 hours it was 34°, which remained constant.

Setting the cans directly on the ice block cooled the cream much more rapidly and to a lower temperature than was the case when the cans were set on the rack an inch above the ice.

The cream of June 10, 11, and 12 was held on the rack 1 inch above the ice until June 18. Each lot was cooled and then put in the can on the following day. The full can was sold on June 18, and the creamery reported as follows: "Cream in good condition; clean, sweet, and has no foreign flavor; acidity 0.25 percent."

A can of cream was placed in the well in direct contact with the ice on July 1. On July 15 (14 days later) it was sold. It was graded as sweet but had a noticeable metallic flavor. The acidity was 0.24 percent. This experiment was made to show how long cream could be held in the ice well. The practice of holding cream for such long periods, however, is not advocated.

In 1929 all of the cream was precooled with water before it was put in the ice well. In the 1930 season some of the cream, and also milk, was not precooled. The data for 1930 are given on pages 11 and 12.

Butter was successfully stored in the ice well.

Throughout the summer of 1929 no objectionable odors were detected in the well or in anything stored. Molds did not develop

on the can rack or in the lower part of the pit. In August a slight mold was noticed on the two upper boards of the well lining, that is, to a depth of approximately 20 inches from the floor of the house.

Sixteen trials were made in 1930 with small amounts (7 to 8 pounds) of cream precooled with water to a temperature of 60.5° F. and then placed in cans directly on the ice block. Average results of the 16 trials were as follows: In 1 hour the temperature dropped to 48.7°; in 3 hours to 40°; in 4 hours to 37°; and in 7½ hours to 34.4°.

Twenty trials were made with small amounts of cream not precooled and set directly on the ice at an average temperature of 85.4° F. In 1 hour the cream had cooled to 61.6°; in 2 hours to 49.3°; in 4 hours to 41.7°; in 5 hours to 38.5°; and in 9 hours to 35.3°.

These results indicated that apparently there was a little to be gained by precooling cream and it is believed that the practice of precooling would pay, especially with large amounts of cream, as the precooled cream used less ice. If greater quantities of cream had been used the temperatures might have been somewhat different from those that were recorded.

Three trials were made with full 10-gallon cans of milk not precooled. These cans were set directly on the ice. The average temperature of the milk was 91.3° F. when the cans were set on the ice block. In 2 hours the temperature was 79.6°; in 3 hours, 72.5°; in 5 hours, 60.3°; in 6 hours, 57.6°; and in 9½ hours the average temperature of the milk was 48°. There was but little variation in the three samples. Each can of warm milk settled into the ice a distance of 3 or 4 inches. The milk was stirred only when temperatures were taken.

Eight full cans of milk were precooled to a temperature of 64.7° F. and set directly on the ice block at 8:30 a. m. In 1 hour the average temperature was 59.6°; in 3 hours, 53.2°; in 4 hours, 49.7°; and in 7½ hours, 44.7°.

In this case, also, precooling was advantageous, not only because of the rapidity of lowering the temperature of the milk, but also because less ice was used. With full cans of milk, precooling was necessary to lower the temperature of the milk in a short time to a point where bacteria multiply slowly.

A can containing 38 pounds of precooled cream collected on August 4, 5, and 6 was held directly on the ice block and sold on August 19 at an average age of 14 days. When the cream was sold the acidity was 0.22 percent. Another can containing 36 pounds of cream collected on August 9, 10, and 11 was not precooled and was held on the ice block until August 24. The acidity of this when sold was 0.22 percent. Both lots of cream were stirred twice daily throughout the storage periods. Apparently the precooling had little effect on the acidity of the cream. However, it is to be borne in mind that the amount of cream put into the can daily on each of the 3 days was only 12 to 13 pounds.

OBSERVATIONS IN 1929–30

The freezing of the block of ice was accomplished in much the same way in 1929–30 as in the previous winter. Freezing started early in December, however, about a month earlier than in the pre-

ceding winter. By February 3 the ice had formed to within 20 inches of the floor.

At this time a box the same size as the trapdoor and rack was placed on the ice directly under the trapdoor. Water was added to the surface of the ice surrounding this box until ice was formed up to the sills of the floor. When the box was lifted out of the ice block there was a depression in the middle of the ice 20 inches deep into which the rack could be lowered. By this method a larger block of ice, the total volume of which was approximately 505 cubic feet, was formed. However, it is doubtful whether the larger size of the block formed in this way was of any practical advantage. The depression filled with water after melting started, and that apparently caused more rapid melting than occurred the year before. The depression which was left by removing the box disappeared about the eighty-fifth day.

The temperatures this winter were considerably higher than those the previous winter (table 1). The mean temperatures for December 1929 and January 1930 were 13.6° and −0.4° F., respectively. However, no difficulty whatever was experienced in getting the ice frozen.

The ice pit was opened and milk and cream storage begun on May 4, about 20 days earlier than the previous summer (table 2). The ice lasted until September 28, a period of 147 days. The rate of melting from the top was greater, averaging 0.67 inch per day, as compared with 0.57 inch per day the previous summer. This is accounted for by the fact that most of the products were not precooled in 1930, which caused greater consumption of ice than in 1929. The nature of the melting from the sides was practically the same both years. The ice melted at the rate of 3.4 cubic feet per day.

The temperatures in the pit at heights of 1, 6, and 12 inches above the ice block, ranged from 4° to 6° F. lower in the summer of 1930 than in the summer of 1929 (table 3). The more rapid melting of the larger ice block in 1930 may have been responsible for this lower range of temperature.

The temperatures that summer in June, July, August, and September 1930, are given in table 1. The mean temperatures for the respective months were nearly the same for both years.

OBSERVATIONS IN 1930–31 TO 1936–37

NATURAL ICE USED TO COMPLETE THE BLOCK

The winter of 1930–31 was a very mild one for this locality. As only about 20 inches of ice was frozen in the pit by February 19. it was deemed advisable to put blocks of natural ice in it to complete the ice cake. Accordingly, two layers of Missouri River ice were put in the pit on February 19 and February 20. These layers were thoroughly chinked with fine ice, but were not frozen so thoroughly as desired. It is estimated that less than 10 short tons of river ice would be required to build up the cake to the desired depth from a 20-inch layer, with sufficient space to store products under the floor. The time required and the cost of the ice are about as shown under 1932–33 and 1933–34. After the well was first opened for use this third season on May 12, the ice lasted 124 days, as compared with 126 days and 147 days for the two previous summers.

The thermometer readings of the temperatures in the pit were practically the same at each height above the ice block as in the summer of 1930 (table 3).

In the winter of 1931–32 no river ice was placed in the ice well. The ice block, as in the winter of 1928–29 and in the winter of 1929–30, was formed entirely by the use of station well water. During this fourth summer the ice lasted 107 days after the well was opened on May 19. The well was opened more than usual during this summer because of an unusually large number of visitors. This was no doubt partly responsible for the shorter period of use.

In the fifth, sixth, and seventh winters, the procedure followed in forming the ice block was about the same as in 1930–31. In the winter of 1932–33 no well water was placed in the pit after January 4. On January 5 and 6 natural ice was put in the pit, 19,170 pounds of river ice being used. The number of man-hours of work required to put this amount of natural ice in the well were as follows:

	Man-hours
Hauling ice in truck, one man 3½ hours	3½
Unloading, two men 1 hour each	2
Packing, chinking, and unloading, two men 5½ hours each	11
Total	16½

The winter of 1933–34 was also considered too mild for forming the pit of ice with well water, and river ice was used. This ice cost 35 cents a ton cut in blocks and elevated to the loading platform. Natural ice was also used in forming part of the ice block in 1934–35 and 1935–36. For these three seasons, the number of days of refrigeration after the well was opened for summer use was 128, 125, and 147 days, respectively.

On comparing the records for the different years, it appears that the placing of blocks of natural ice in the ice well may result in a fairly solid ice cake. However, by making the ice block with well water, a little patience and very little effort are required to put a few pails of water in the well daily, although 8 to 10 weeks of freezing weather may be required to complete the work. Experience has shown that this gives a solid ice cake in good freezing weather and is a dependable method. The process, however, may appear tedious if spread over several months.

All things considered, it appears that the practice of putting blocks of natural ice in the ice well would probably be the most advantageous for the dairy farmer residing within a reasonable distance of a supply of good natural ice. When blocks are used, all the work can be completed in a relatively short time. The hauling, unloading, chinking, and freezing together can be accomplished in a few days of freezing weather. If the ice well is not located conveniently to the water supply, the practice of using blocks would unquestionably be the most practicable. Also, experience has shown that water will freeze to a satisfactory depth for good-sized blocks when it is exposed as in a river or pond, while rather slow progress is being made in the bottom of the ice well under identical weather conditions.

CARE OF THE WELL

Keeping the house over the pit tightly closed in summer except when opening the pit to store or remove products in it provides suffi-

cient air circulation. Products stored in the pit keep well, and no offensive odors were detected in the well during the summers the well has been in use. Slightly off flavors were noticed in sweet cream stored in the ice well in 1930.

In getting the well ready for use for the winter of 1931–32, the walls were thoroughly disinfected with a blue-vitriol solution, followed by the use of a solution of calcium hypochlorite the next day. This was the first and only time during 9 years of use that the walls have received a disinfecting treatment.

OBSERVATIONS ON A CONCRETE ICE WELL

The success which has attended these experiments with this ice well at Mandan, N. Dak., led the Bureau of Dairy Industry to conduct experiments with a different type of ice well at the United States Dairy Experiment Station at Ardmore, S. Dak.[3] The well at Ardmore was made circular in form instead of square, and was lined with a concrete wall varying from 4 to 7 inches in thickness. The floor and house above the pit are similar to those at Mandan. The Ardmore well is located in a corner formed by the north wall of a covered alleyway and the west wall of the milk room. On the west it is sheltered by a barn.

Freezing was started on December 6, 1929. Little difficulty was experienced in getting the floor coated with ice, but the weather was intermittently warm and cold in December, and very little ice formed in that month.

In January the temperature was zero or below on 27 days of the month, and freezing in the well was rapid. On an average, 50 gallons of water was poured into the well daily. This amount of water formed approximately 1.8 inches of ice. In February and March the weather was moderate and only a little ice formed in these months. At the end of the freezing period for the well, March 2, there was a solid cake of ice 63 inches deep, which had a volume of approximately 232 cubic feet.

By April 1 the ice block had melted to a depth of 58 inches, and by May 1 it was only 39 inches deep and had melted away from the circular wall about 7 inches. By June 15 the ice had completely melted.

The reason for such rapid melting so early in the season is not definitely known, but the assumption is that the concrete, which was not insulated, conducted heat from the surrounding ground into the ice chamber. Another reason may be the close proximity of the well to a water main and sewer line. Also, on account of the fact that the well is in a somewhat sheltered location, all of the surrounding soil may not have frozen. It is believed that the noninsulated concrete wall was the chief factor in the rapid melting.

Many suggestions have been made concerning the form of construction, material to use, and the method of operation of an ice well. Some of these are: (1) Use galvanized iron as a lining; (2) treat the lumber with creosote or other preservative to prevent rotting; (3) pack straw or sawdust between wooden lining and outside soil to

[3] These observations were made by Ray H. Smith, in charge of the dairy work at the Ardmore Station.

provide better insulation; (4) install water coils in bottom of pit and freeze ice around them so as to provide a supply of cold water for cooling milk in the summer; (5) fill the well with snow instead of ice; and (6), make the pit deeper to provide a larger supply of ice.

Some of these suggestions may have considerable merit and may be considered in future experimental work.

CONCLUSIONS

Ice wells constructed according to the method employed and material used at Mandan, N. Dak., are practical and successful under the temperature conditions prevailing in that section. It is thought that such ice wells are adapted to any locality where winter freezing temperatures are sufficiently low and extend over long enough periods to freeze enough ice in the pit.

If a supply of natural ice from a lake, pond, or river is within reasonable hauling distance and can be obtained at a low price, it may be advantageous to fill the well with natural ice. By doing this the job can be finished in a few days. Otherwise the job of filling may extend over a month or two, depending on the weather conditions.

Sufficient ice can be made to last over a period of approximately 4 months during the summer for ordinary dairy-farm use, if care is taken to conserve it.

In the two experiments described, lumber has been the best material for lining the well. Noninsulated concrete was not suitable as used.

Milk, cream, and butter can be successfully stored in the ice well for reasonable periods of time. No offensive odors result when care and cleanliness are practiced.

For small lots of cream, precooling with cold running water is not necessary, but it is desirable. For large lots of cream it is advisable to precool with cold water, to conserve the ice and to bring about more rapid cooling. It is advisable to precool whole milk before storing it in the ice well.

The ice well can be made at low cost. The lumber used in the well can be cheap and rough. The house over the pit should be tight and durable, but it need not be expensive.

IMPORTANT POINTS IN CONSTRUCTION AND OPERATION

(1) Locate the well close to a clean water supply and to the milk house; (2) provide good drainage, both inside and out; (3) be sure that the house floor which covers the pit is tight and well insulated; (4) keep the house tightly closed and open it only when necessary in summer; and (5), if milk or cream is spilled on the ice or in the pit clean it up immediately to avoid objectionable odors.

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Division of Dairy Cattle Breeding, Feeding, and Management	R. R. GRAVES, *Chief.*

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